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5-73-62-2

THE EFFECT OF HYDROGEN ON ALUMINUM: AN ANNOTATED BIBLIOGRAPHY

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Compiled by
C. G. GROS

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Lockheed

MISSILES & SPACE COMPANY

A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SUNNYVALE, CALIFORNIA

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ABSTRACT

This work treats of the effect of hydrogen on aluminum, with reference to welding at room temperature and the ultimate reliability of aluminum thus treated in space applications; it covers the period from 1950 through 1962. A few citations to non-ferrous metals which might lead to information about aluminum have been included. The resources of the Technical Information Center, Lockheed Missiles & Space Company, were utilized.

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1. Adams, D. F. and W. G. Hull
THE METAL ARC WELDING OF ALUMINIUM-MAGNESIUM SILICIDE ALLOY, H. 30. Ministry of Supply, Gt. Brit. Final summary rept. S & T memo. no. 6/58, JSRP Control no. 581278. Jun 1958. 1v. (In cooperation with British Welding Research Association). ASTIA AD-203 932.

An investigation of the causes of cracking and other weld defects experienced during the fabrication by metal arc welding of H. 30 alloy (Al-Mg-Si) extrusions with Al-5% Si type electrodes. The cracking was generally delayed and occurred longitudinally at the center of the weld but sometimes occurred at the weld junction. The investigation included (1) the factors affecting weld metal porosity, (2) the relationship between thermal cycle and heat-affected zone properties, and (3) the development of filler alloys to increase the weld metal strength and eliminate cracking. The cracking of the weld metal produced by the metal arc welding of H. 30 alloy extrusions with Al-5% Si type electrodes was accounted by an Si content of less than 2%; the minimum required Si content in the weld metal appears to be 3.5%. Weld porosity resulted from H introduced by (1) the electrode coating, as water of crystallization or as free moisture, or (2) by corrosion products at the core wire surface. Welds produced with filler alloys containing 12 to 14% Si were more crack resistant than those made with 10% Si alloy. Filler alloys depositing weld metal with 3.5% Si, 1 to 1.5% Mg, and 0.8 to 1.7% Cu gave welds with high crack resistance and tensile strengths of 18 to 20 tons/sq. in. The effect of thermal cycling on the properties of heat-affected zones in metal arc welds appeared negligible.

2. Alov, A. A., G. V. Bobrov, and Shmakov, V. M.
The problem of the nature and origin of gas pores in welded joints. WELDING PRODUCTION 3:17–21, Mar 1961.

It is during the solidification periods that the formation and development of porosity in welded joints – which is connected with the processes whereby gases are generated in the metal, or with the separation of the gases out of solution – occur. Since hydrogen is soluble in all technically important metals and alloys, it is of great importance in the formation of pores in welds. In several metals, including aluminum, hydrogen forms interstitial solid solutions. The concentration of hydrogen in such metals depends upon external conditions and temperature. The principle causes of the formation of gas pores in welds, stemming from micro-nuclei, are (1) the occurrence of reactions giving rise to the formation in metal of insoluble gases, and (2) the interdendritic and intradenditic contraction of metal. Where no reaction occurs which can result in the formation of insoluble gases in metal during the solidification period, micronuclei can only be the result of metal shrinkage.

3. Bailey, J. C. and G. W. Eldridge
Factors influencing the properties of welds in aluminum. LASTECHNIEK 27:75–83, Apr 1961. (In English)

Review of Tig and Mig welding procedures of aluminum and its alloys. Discusses the influence of impurities, temperature, filler rod composition, hydrogen, extent of heat zone and welding speed and current on discontinuities.

4. Berger, L. W., D. N. Williams, and R. I. Jaffee
THE EFFECT OF HYDROGEN ON THE MECHANICAL PROPERTIES OF TITANIUM-ALUMINUM ALLOYS. Battelle Memorial Inst., Columbus, Ohio. Summary rept. 1 May 56–30 Apr 57. 28 Jun 1957. 35p. [Contract DA(I) 33-019-505-ORD(P)-7, Proj. TB 4-15] ASTIA AD-134 316.

An appraisal of the effects of H on the properties of binary Ti-Al alloys containing 2.5, 5.0, and 7.0% Al and ternary alloys containing the following interstitial levels at each of the Al contents: 0.10 and 0.15% O; 0.02 and 0.05% N; and 0.05 and 0.10% C. All alloys were tested at the vacuum annealed and 150 ppm H levels. If impact embrittlement was encountered at 150 ppm H with the binary alloys, they were subsequently evaluated at 75 and 225 ppm. If an alloy was not embrittled by 150 ppm, additional H levels of 300 and 450 ppm were prepared. Ternary alloys were evaluated at one additional H level dependent on whether or not an addition of 150 ppm was sufficient to cause impact embrittlement. In general, the addition of interstitials to the base alloys did not materially affect the results. Increasing the Al content increased the apparent solubility of H in Ti-Al alloys. For unalloyed Ti and Ti-2.5Al, H additions up to 230 or 245 ppm had no detrimental effects on tensile properties, but the notch-bend impact strength of both materials was seriously lowered by the addition of 75 to 80 ppm H, an addition which was sufficient to show hydride in the structure. Interstitial ternary additions to Ti-2.5Al appeared to increase the solubility of H. Hydride did not appear in the microstructure of Ti-5Al and Ti-7Al binary alloys until 315 and 415 ppm H, respectively, were added. The increased solubility of H was associated with a strengthening without loss in ductility and an increased tolerance to impact embrittlement. Thermal exposure of all alloys for 1000 hr at 1000° F was not detrimental at 2.5 and 5% Al levels, but loss of tensile ductility after exposure was noted for alloys containing 7% Al. This embrittlement may be related to the precipitation of Ti_3Al.

5. Brace, A. W.
Gas removal from molten aluminum alloys.
FOUNDRY TRADE JOURNAL 93(1870):3–11, 1952; 93(1882):359–361, 1952 (discussion).

Discussion of the sources of hydrogen and of the mechanism of absorption, as well as factors affecting the amount of porosity and its distribution. Also, conditions necessary for the removal of gas from melt.

6. Bradaschia, Clovis
Problems of gases in aluminum and its alloys.
BOLETIM DA ASSOCICAO BRASILIERA DE METAIS 7:20–35, 1951. (In Portugese)

Discussion of the part played by H_2 in the formation of pinholes, and of the mechanism of their formation, is followed by a discussion of methods for eliminating gases.

7. Brammer, W. N.
Melting practice for aluminum casting alloys.
MODERN CASTINGS 34(4):31–36, Oct 1958.

Discussion of some inherent characteristics of Al alloys, including the tendency of molten Al to absorb hydrogen, and the results in melting practice; the design and operation of Al holding furnaces; furnace melting equipment; temperature control; grain refining; and fluxing Al alloys.

8. Brandt, J. L. and C. N. Cochran
Gas content of solid aluminum by solid extraction and vacuum fusion. JOURNAL OF METALS 8:1672–74, 1956.

A discussion of two methods of determining hydrogen content in aluminum, and the preparation of suitable samples; agreement of analyses of similar aluminum specimens by the two methods also established and discussed. It was concluded that little additional hydrogen is evolved in the vacuum fusion of a sample already degassed by solid extraction.

9. Castro, R., and M. Armand
Les gas dans l'aluminium et ses alliages.
REVUE DE METALLURGIE 46:594-616, 1949.
(In French)

Reviews the literature; discusses gas in Al and Al alloys, the state of gas in Al, the influence of gas inclusions, and remedial measures. Bibliography.

10. Chandley, Dixon; Clyde M. Adams, Jr; and Howard F. Taylor
A quantitative evaluation and importance of hydrogen in aluminum founding. AMERICAN FOUNDRYMEN'S SOCIETY. TRANS. 63:607-614, 1955.

Considers the effect of hydrogen content on the tensile properties of 195 alloy; techniques for degassing Al; and sources of hydrogen. Tables, graphs, photographs.

11. Chapman, G. D.
Light-alloy foundry and gas problem. LIGHT METALS 13:326-31, 1950.

The physics, chemistry and mechanics of hydrogen pickup; effects of dissolved hydrogen; physical methods of controlled gas additions; and chemical methods of removing dissolved hydrogen.

12. Chatterjee, G. P., K. C. Shome, and R. P. Ganguli
Studies on pin holes in aluminum. INDIAN INSTITUTE OF METALS. TRANS. 5:311-321, 1951.

In cast aluminum and its alloys, pin holes are due principally to hydrogen, which under certain definite conditions will, on adsorption and diffusion, form bubbles. Basic concepts re: solution, adsorption and diffusion of hydrogen, with graphs and table.

13. Dardel, Y.
Hydrogen in aluminum: Method of determination – Effect on pore formation. METAL INDUSTRY 76:203–6, 1950.

Treats of the effect of pore formation during solidification, heat treatment, and welding, as well as discussing a method of determining hydrogen content in aluminum.

14. Eichenauer, Walter
Diffusion and solubility of hydrogen in metals. MEMOIRES SCIENTIFIQUES 57:943–948, 1960. (In French)

Hydrogen diffusion and solubility coefficients were determined by measuring the degassing rate of aluminum and other metal specimens following exposure to hydrogen and liquid hydrogen.

15. Eichenauer, Walter, Karl Hottenbach, and Alfred Pebler
Solubility of hydrogen in solid and liquid aluminum. ZEITSCHRIFT FUER METALLKUNDE 52:682–684, 1961. (In German)

Measuring the solubility of hydrogen in solid and liquid aluminum, at pressures of 200–600 Torr with extrapolation to 760 Torr, at 360–1050°C. Solubility interpreted in terms of Sieverts' law.

16. Eisenreich, H.
Entgasung von Aluminiumlegierungen. TECHNIK 5:310–315, 1950. (In German)

The solubility of hydrogen in aluminum and the degasification of aluminum alloys; vacuum and chlorine degasification, the latter with gas and magnesium chloride.

17. Erdmann-Jesnitzer, F.
Gas content and hot shortness of aluminum alloys. METALL 13:405–407, 1959.
(In German)

Discussion of the relationship between hydrogen content, hot shortness and casting temperature in aluminum alloys.

18. Feinberg, I. J.
Tensile properties of porosity-graded 195 alloy.
NON-DESTRUCTIVE TESTING 15:168–173, 1957.

A discussion of the quantitative determinations of damage to ultimate tensile strength, to yield strength, and to per cent elongation attendant upon elongated hydrogen gas porosity in aluminum alloy 195. Radiographic classification procedure for obtaining reliable porosity grade assignments before assessing damage.

19. Feinberg, Irving J. and John D. Grimsley
TENSILE PROPERTIES OF POROSITY-GRADED 355 PLASTER-MOLD ALUMINUM ALLOY.
Naval Ordnance Lab., White Oak, Md. NAVORD rept. no. 5690. 20 Aug 1957. 24p.

Review of the nature of hydrogen gas porosity in plaster mold 355 aluminum alloy. Reference radiographs providing bases for association with derived tensile properties were prepared. Quantitative determinations of the damage by elongated hydrogen gas porosity to ultimate tensile strength and to yield strength were obtained. Expected minimum properties for material containing four degrees of porosity are given.

20. Fiala, Antonin and Zdena Tolarova
Hydrogen as the cause of porosity in aluminum and its alloys. SLEVARENSTVI 2(6):162–7, 1954. (In Czech)

In tracing the formation of blow holes, additions of sulfur monochloride and vacuum extraction were used. Graphs, diagram, photographs and tables.

21. Gnedovskii, I. E.
Causes for the formation of pores during electric arc welding of silumin. SVAROCHNOE PROIZVODSTVO 11:13–15, 1955. (In Russian)

Discussion of factors which affect porosity in the aluminum-silicon alloy, silumin, and recommendations for its avoidance. Diagram, graphs, micrographs.

22. Griffith, C. B. and M. W. Mallett
Determination of hydrogen in wrought aluminum alloys. ANALYTICAL CHEMISTRY 25:1085–87, 1953.

A study of porosity in wrought aluminum welds. In order to isolate hydrogen sources and to control porosity (since the determination of suspected hydrogen in light metals has produced erratic results), a workable determination method was sought. It was concluded that a modification of the tin fusion method is both rapid and capable of determining hydrogen contents of 0.1 cc per 100 grams or greater.

23. Hofmann, Wilhelm and Juergen Maatsch
Hydrogen solubility in aluminum, lead and zinc melts. ZEITSCHRIFT FUER METALLKUNDE 47:89–95, 1956. (In German)

Determination of the gas contents of metals is discussed with reference to method and degree of accuracy. Diagrams, graphs, tables.

24. Hummitzsch, W.
Hydrogen content and mechanical properties of weld metal in arc welding with coated electrodes. Influence of storing time. SCHWEISSEN UND SCHNEIDEN 10:476–480, 1958. (In German)

Tensile testing of welded joints in order to determine the influence of hydrogen. It was concluded that hydrogen escapes in storage and that, on the whole, the strength of weldments improve. .

25. Kalpers, H.
Removing hydrogen from aluminum melts.
ARCHIV FUER METALLKUNDE 3:427–8,
1949. (In German)

Additions merely flushing gaseous H_2 from aluminum melts are unsatisfactory because of the likelihood that H_2 both dissolves in and combines with aluminum. Chlorine gas, or an undefined material called "Flussum-Al," are recommended for removal of chemically combined H_2.

26. Korol'kov, G. A. and I. I. Novikov
Effect of gas content on hot brittleness of aluminum alloys. IZVESTIYA AKADEMII NAUK SSSR,
OTN, METALLURGIYA I TOPLIVO 2:19 23,
1959. (In Russian)

Melts of various composition were subjected to hot shortness testing, in the original state and also after increasing hydrogen content by steam treatment. Reducing effect of hydrogen on linear shrinkage and ductility discussed.

27. Kostron, Hans
Aluminium und Gas. ZEITSCHRIFT FUER
METALLKUNDE 43:269–284 and 373–387,
1952. (In German)

Discussions of the equilibrium between aluminum and hydrogen above and below the melting point, the diffusion of hydrogen in aluminum, the influence of aluminum alloying elements on hydrogen absorption, and blisters and pores in wrought alloys.

28. Kostron, H.
Die Verfahren zur Bestimmung des Gasgehaltes
von Leichtmetallen. METALL 6:115–123,
1952. (In German)

Principles and methods of determining gas content of Al and Al alloys, hydrogen solubility, and a critical review of methods utilized in laboratories and plants.

29. Mallett, M. W.
Gases in metals. STEEL 139:95–98, 8 Oct 1956.

Methods for the determination of hydrogen and other gases in metals. Problems caused by the hydrogen embrittlement of large forgings and disruption of bond between babbitt facings and steel bases of friction bearings, as well as the gas-induced embrittlement and porosity of weldments. Discussion of the progress made in degassing ferrous, non-ferrous and light metals.

30. Mannchen, W.
Siluminveredelung u. Wasserstoff. METALL 4:377–79, 1950. (In German)

Literature review re refining of Al Si alloy with Na additions; silumin refining and the hydrogen effect; and discussion of a possible mechanism caused by H_2 released from cooling melt. Bibliography.

31. Nikiforov, G. D. and A. G. Makhortova
The conditions for pore formation when welding aluminum and its alloys. WELDING PRODUCTION 3:9–16, 1961.

Investigations into the mechanism and conditions of pore formation in the weld metal during the welding of aluminum and its alloys have been made possible by the development of a method and an apparatus for the determination of the hydrogen content in the weld metal. A large number of such investigations indicate that the basic reason for the occurrence of pores, during the casting and welding of aluminum and its alloys, is the liberation of dissolved hydrogen from the liquid metal during cooling. In addition to hydrogen content in excess of 0.69 cm 3/100 g, the presence of embryo micro-cavities also accounts for this pore occurrence. When the concentration of hydrogen in the weld pool exceeds the amount cited above, the possibility of the partial degassing of the weld pool is shown to arise through the floating up of the bubbles which have formed in it.

32. Nikiforov, G. D. and A. G. Makhortova
The origins of dissolved hydrogen in aluminum welds. WELDING PRODUCTION 4:12–21, 1961.

Despite the work alreay done on the appearance of pores during the welding of aluminum and its alloys, and on their causes and the manner in which they arise, one of the many unanswered questions has to do with the sources of hydrogen most likely to give rise to a concentration of this element in the weld pool. The authors conclude that (1) the most substantial and basic source of hydrogen is water, adsorbed onto the surface of the wire and the parent metal; (2) the figures quoted on the amount of hydrogen given off from these surfaces when they are heated – with the various methods of surface penetration – make it possible for the best method of pre-welding treatment to be chosen; and (3) more pore-research is needed to find rational ways of preparing these surfaces before welding, to determine the best pre-welding storage conditions, and to develop a technique of combining gaseous hydrogen with compounds which are both in soluble in metal and stable at high temperatures.

33. Nonveiler, F., A. Lahodny, and S. Tezak
Gas in aluminum alloys. TEHNICKI PREGLED
5:51–56, 1953. (In Croatian)

Brief discussion of the source of gases in solid and molten aluminum, and their effect upon the quality of the final product. Some methods for semi-quantitative control of gas content in molten aluminum are described, and a satisfactory, simple laboratory control equipment setup is described. A degassing chemical agent is described in the second half of the paper. Immediately after the chemical reaction has occurred the escape of gases from molten metal is slow; escape reaches its peak after six minutes, and in twenty-five minutes is virtually finished.

34. Obreski, J.
What to do about porosity in aluminum castings.
IRON AGE 181:71–74, 15 May 1958.

Monarch Machine Tool Co. study of castings methods and their influence on porosity. The solidification rate; effects of this and of gases; gas porosity prevention by the slow cooling of molten metal; effect of flux; and obtaining of quick solidification by melting pure Al first, then adding Cu, Si or Mg-rich pre-alloys.

35. Opie, W. R. and N. J. Grant
Effect of hydrogen on mechanical properties of
some aluminum alloys. FOUNDRY 78:104–109,
209–210, Oct 1950.

The possibility of studying H_2 solubility in a system containing water vapor is indicated by some experiments. There is no evidence that dissolved H_2 embrittles Al, but H_2 which precipitates interdendritically when Al solidifies, markedly weakens the metal. Lesser amounts of hydrogen than are needed to produce some pinhole porosity will yield microscopic cavities greatly decreasing the tensile strength and elongation of a 5% Si Al alloy.

36. Opie, W. R. and N. J. Grant
Hydrogen solubility in aluminum and some aluminum alloys. JOURNAL OF METALS (AIME. TRANS.) 188:1237–1241, 1950.

Hydrogen, precipitating during cooling and solidification in molten aluminum and aluminum alloys, is the main cause of pin hole porosity in ingots and castings. The effects of temperature and pressure on hydrogen solubility in pure aluminum have been investigated, but few data exist on the solubility of hydrogen in the aluminum alloys. This investigation checks reported results re pure aluminum, and shows the effects of silicon and copper additions on hydrogen content in molten alloys. The pressure range investigated was from 50 to 800 mm of mercury, the temperature range from 700° to 1000°C. Silicon and copper (the latter more than the former) decrease the solubility of hydrogen in aluminum. Hydrogen solubility in Al, Al-Cu, and Al-Si alloys may be expressed in an equation of the general form

$$\log_{10} S = -\frac{A}{T} + B \ ,$$

where S = solubility in cubic cm. of H at standard conditions per 100g of metal.

37. Preston, Oliver, et al.
RESEARCH ON MECHANICAL PROPERTIES OF SINTERED ALUMINUM POWDER. Massachusetts Inst. of Tech., Cambridge. Progress rept. no. 20, 1 Jul–1 Oct 1957. 3p. (Contract AF 33(616) 284) ASTIA AD-145 015.

Oxide-metal structure studies: Spherical particles of Al_2O_3 were deposited on -325 mesh Cu by decomposition of nitrate at 450°C. Small areas (10 μ) free of oxide particles showed small recrystallized grains after extrusion. Testing is in progress on 4 materials produced by internal oxidation of the more dilute Cu-Si and Cu-Al alloys at 750°C. Cu-metal oxide mechanical mixtures: The following new alloys which were mixed by the Waring Blendor technique and reduced in H at 260°C are being readied for sintering and extrusion: (1) -200 mesh Cu plus 10 vol-% of Alon C alumina; (2) 5-μ Cu plus 10 vol-% of Monsanto alumina; (3) 5-μ Cu plus 10 vol-% of carbon black; (4) 1-μ Cu plus 10 vol-% of Thoxide; (5) 1-μ Cu plus 10 vol-% of Ti oxide; and (6) 1-μ Cu plus 10 vol-% of SiO_2. Alloys 2 through 6 were prepared to investigate the effect of dispersing substances in a matrix of Cu whose chemical composition differs from that of Al_2O_3. Additional specimens of 1- and 5-μ Cu, respectively, plus 10 vol-% of 0.02 Al_2O_3 were prepared for tests at 350° and 550°C to evaluate the temperature dependence of the strength of these alloys. Dilute Ni-alloy study: Steps were taken towards procuring Ni alloy powders containing small amounts of Ti, Cr, or Al for preparing fine dispersions of oxides of the solute metal in Ni. Preliminary studies in the Ni-Al system showed that at temperatures as low as 900°C a very fine dispersion of Al_2O_3 could be produced by internal oxidation. A structure that could not be interpreted by X-ray diffraction was obtained when fine Ni-Al powder was produced from Raney-Ni catalysts.

38. Pumphrey, W. I. and E. G. West
Metallurgy of welding aluminum and its alloys.
BRITISH WELDING JOURNAL 4:297–306,
Jul 1957.

Primarily a consideration of fusion welding. Observation of common defects from which Al welds may suffer if correct metallurgical principles are ignored. Discussion of the causes of defects in relationship to the effects of temperature, oxygen, hydrogen, and other elements in the parent metal and weld, as well as of post-welding treatment. Summary of metallurgical studies leading to the successful welding of Al and its alloys.

39. Ramamurthy, S.
Technique of melting and treating non-ferrous alloys. TISCO (TATA IRON & STEEL INSTITUTE. JOURNAL) 9:92–98, 1962.

Reviews of gases in metals, including their effect on mechanical properties, density and soundness of aluminum and nickel alloys. Also surveys grain refinement and modification of aluminum alloys.

40. Ransley, C. E., D. E. J. Talbot, and H. C. Barlow
Aparatus for determining gas content of aluminum alloys during melting and casting.
ALUMINIUM 34:643–646, 1958. (In German)

41. Ransley, C. E. and D. E. J. Talbot
Hydrogen porosity in metals with special consideration of aluminum and its alloys.
ZEITSCHRIFT FUER METALLKUNDE
46(5):328–337, 1955. (In German)

The determination of hydrogen content in aluminum and aluminum alloys; determination of porosity; solubility of hydrogen in aluminum and aluminum alloys; diffusion of hydrogen in aluminum and other metals as a function of temperature; and the mechanism of pore formation. Diagrams, graphs, tables.

42. Ransley, C. E. and D. E. J. Talbot
Routine determination of hydrogen content of aluminum and aluminum alloys by hot-extraction method. INSTITUTE OF METALS. JOURNAL
84(Pt 2):445–452, 1956.

The advantages of the hot-extraction method of the measurement of hydrogen content in aluminum emphasized, with a procedure giving satisfactory results over a long period of time in routine use. The absolute accuracy and main sources of error were also investigated in this method.

43. Rohner, F.
Entwicklung u. heutiger Stand der Bestimmung von Gasen in Metallen. SCHWEIZER ARCHIV
23:243–8, 1957. (In German)

Determination of gases in metals (present status and development), with special reference to hydrogen in aluminum. A review of apparatus and methods of gas analysis in solid and molten metals.

44. Rosenthal, H. and H. Smolen
ULTRASONIC ATTENUATION IN CAST ALUMINUM. Frankford Arsenal, Philadelphia, Pa. Rept. no. R-1500. Mar 1959. 20p. (Proj. no. TB4-002) ASTIA AD-216 142.

Techniques have been developed in recent years for producing high quality aluminum castings. Since radiography does not clearly distinguish between this quality and the ordinarily acceptable grade, a nondestructive test method is needed. Aluminum test plates (7% Si-0.3% Mg) were cast with a chill on one edge and a riser at the opposite edge. Near the chill the properties are 38,000 psi ultimate tensile strength, 26,000 psi yield strength and 8 percent elongation; near the riser the properties fall off to 33,000 psi ultimate tensile strength, 26,000 psi yield strength, and 2 percent elongation. Radiographic examination was not sensitive to this change. Ultrasonic attenuation measurements were made at various locations in the plates. There was a definite increase in attenuation in a direction away from the chill edge. Other experiments have been made on samples (5% Si) with various gas contents. The attenuation characteristics are markedly affected by the presence of gas and micro-shrinkage in the samples.

45. Srawley, J. E.
HYDROGEN-EMBRITTLEMENT SUSCEPTIBILITY OF SOME STEELS AND NONFERROUS ALLOYS. Naval Research Lab., Washington, D. C. Final rept. NRL Rept. no. 5392. 19 Oct 1959. 25p. ASTIA AD-228 573.

Several steels and nonferrous alloys were tested to determine their comparative susceptibilities to hydrogen embrittlement. The criterion used was the ratio of the lowest nominal stress at which a hydrogen-charged notched tensile specimen fractured within 100 hours (the "static-fatigue limit") to the notched tensile strength of the uncharged material. Severe conditions of electrolytic charging were used (24 hours at 0.5 amp per square inch) so that a very slight degree of susceptibility might be detected.

46. Srawley, J. E.
IRON-CHROMIUM-ALUMINUM ALLOYS. Naval Research Lab., Washington, D. C. Final rept. NRL rept. no. 5124. 18 Apr 1958. 17p. ASTIA AD-158 947.

Alloys with up to 25-percent chromium and 11-percent aluminum were produced by vacuum melting and hot worked by forging. Tensile properties at room and elevated temperatures were determined, and their resistance to oxidation in air and attack by the combustion products of residual fuel oils was studied. Alloys containing about 5-percent aluminum and 25-percent chromium appear to offer excellent prospects of improved service as boiler-tube support materials when compared with type 310 stainless steel, which is commonly used. It has been shown in an earlier report that application of aluminum coatings to the type 310 steel offered little prospect of improved life. The vacuum induction melting process as applied to these alloys has been studied. The exclusion of air during melting and pouring is important in controlling the cleanliness of the product, but the level of dissolved oxygen is controlled by the aluminum content and is so low that prior deoxidation with hydrogen or carbon cannot affect it. The possibilities of control of carbon and nitrogen require further study.

47. Steigerwald, E. A., F. W. Schaller, and A. R. Troiano
THE LOWER CRITICAL STRESS FOR DELAYED FAILURE. Case Inst. of Tech., Cleveland, Ohio. Rept. on Solid State Research and Properties of Matter. WADC TR 59-445. Aug 1959. 30p. (Contract AF 33(616)6419, Proj. 7021) ASTIA AD-234 455.

The lower critical stress was defined as the minimum stress necessary to produce sufficient hydrogen segregation to initiate a crack. Using this definition and the Boltzmann distribution law, the influence of notch acuity, yield strength, temperature, and initial hydrogen content on the lower critical stress was rationalized. For a given test temperature and hydrogen content, the interaction energy, which is stress dependent, was constant and independent of notch geometry as well as strength level. Increasing notch acuity and strength level merely permitted the development of the critical interaction energy at a lower value of applied load: hence, a lower static fatigue limit resulted. From room temperature to -50° F, the influence of temperature on the lower critical was adequately explained by taking into account the distribution law and the influence of temperature on the yield strength. Below -50° F an anomolous behavior was observed which was attributed to a strong interaction between dislocations and hydrogen. The interaction energy at the lower critical stress for one particular set of test conditions was estimated to be approximately 0.04 ev.

48. Walther, W. D., C. M. Adams, and H. F. Taylor
Better aluminum castings. MODERN METALS
10:44--46, Mar 1954.

Discussion re application of a test introduced in England by W. H. Baker. Method of performing this reduced pressure test for evaluating the melt quality from the point of view of dissolved hydrogen, the effect of reduced pressure, and the improved tensile properties obtained by degassing aluminum alloys.

49. Westendorp, G.
Some remarks on the weldability of aluminum.
LASTECHNIEK 27:70-74, 1961. (In English)

Considers decrease in strength brought about by welding heat and porosity in welds of pure (and commercially pure) aluminum and 6061 aluminum alloys. Also, the effect of diffusion coefficient and solubility of hydrogen.

AUTHOR INDEX

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